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ABSTRACT

The Learning in Science Project investigated teaching and learning in science at the Form 1 to 4 level to identify some of the key difficulties in this subject area and to find ways of overcoming such difficulties. Included in this final report are: (1) brief accounts of the three major phases of the research; (2) a list of papers derived from the project; and (3) recommendations of the project's advisory committee. The first (exploratory) phase used structured/unstructured interviews and observations to identify problems related to difficulties in understanding scientific ideas/theories, conceptions held by students, science and everyday language, experiments, and instructional strategies. The second phase, also using interviews/observations focused on the learner, examining students' views about the behavior of phenomena, and their classroom experiences and outlook on science. Four groups were formed in the third phase to examine issues related to concepts in the specific content areas. These include physics (force, friction, gravity), biology (living, animals, plants), chemistry (particles, physical change, chemical change), and an activities group, exploring solutions to some mismatches isolated in the work on students' classroom experiences. Seven recommendations are provided, focusing on dissemination of the project's findings to help teachers assess and modify their instructional strategies. (JN)

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LEARNING IN SCIENCE PROJECT (FORM 1-4)

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30 June, 1982

The Director-General,
Department of Education,
Private Bag,
WELLINGTON.

Dear Mr. Renwick,

In 1978, your Department offered a contract to the University of Waikato to initiate a Learning in Science Project to make a detailed study of the teaching and learning of science at the Form 1 to 4 level, to identify some of the key difficulties in this subject area, and to find ways of helping teachers overcome such difficulties. During the three years of the contract, the Project team has produced more than 50 working papers, spoken at numerous conferences and teachers' refresher courses, cooperated in action-research programmes with several groups of teachers in various parts of the country, and produced video-tapes and other materials for the in-service training of science educators.

Your Department has already received copies of all our Working Papers, journal articles and other materials, but to summarise the activities of the Project, we now have pleasure in submitting to you, as our final report,

(i) brief accounts of the three major phases of the research*, including

(ii) a list of papers deriving from the Project; and

(iii) the recommendations of the Project's Advisory Committee, for your consideration.

We are grateful for the financial and general assistance which you personally and your Department have already given us, and for the continuing support represented in a further research contract in the area of primary school science. We trust that the results of our efforts will lead to further improvements in the teaching of science in New Zealand schools.

Yours sincerely,

P.S. Freyberg R.J. Osborne

Co-Directors, Learning in Science Project
University of Waikato.

* to be published subsequently in the N.Z. Science Teacher, for the information of teachers.

A REPORT ON THE FIRST PHASE [1]

Ross Tasker, Peter Freyberg, Roger Osborne

The LEARNING IN SCIENCE PROJECT was a research investigation funded by the New Zealand Department of Education and based at the University of Waikato. The aim of the project was to make a study of the teaching and learning of science at the Form 1-4 level, to identify some of the key difficulties in this subject area, and to find ways of overcoming such difficulties.

WHY A LEARNING IN SCIFNCE PROJECT?

> "... the science teacher did up this tin and he added water to it and it all went inside - all crushed up. That was a good one, when he added cold water to it. (So what did he do? He put a little bit of water in it, heated it up ...) No, we just saw him tip the water over it and it all went in - squeezed all up. (Why did it do that?) We don't know."
>
> (Form 3 pupil)

All teachers of science are concerned about what their pupils are taking out of the science experiences organised for them. The basis of that concern is an awareness that much of what we teach seems so difficult for so many of our pupils. Sometimes, when we think they have got the point we are making, a question exposes a view quite different from that intended or expected as an outcome of the lesson.

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1. Some material in this article is also included in a chapter describing the Learning in Science Project in Harlen, W (Ed) New Trends in Primary School Science, Paris: UNESCO (in press)

O. What do you think about evaporation now? (to a Form 2 girl who had just finished evaporating a copper sulphate solution to dryness)

G. Um... the heat gets too much for the water so it just turns into steam...

O. Steam, what's that?

G. ... it's water and gas.

O. What would the gas be?

G. Either air or carbon dioxide... one of them.

Of course it isn't always like that, we do have our successes.

> "The way we did it was really good... we would take our ticker-tape and cut it up and make a graph out of it... I learnt a real lot from that because it sort of showed you what you did... that was an incredibly good experiment... it stands out in my mind today because I remember I learnt quite a lot from that... because we had a real good teacher too."
>
> (Form 6 pupil reflecting on Forms 3 and 4 science)

Unfortunately, we are rarely well-informed about either the good or the bad.

> "I have no feedback... I have no idea of my success or failure... I have no idea of how I am succeeding and I think that is a shame."
>
> (Form 2 teacher)

The reasons for this paucity of feedback are no doubt complex but pressures of the syllabus and the classroom give us little time for reflection and analysis of what we have taught and what pupils have learnt. Often we are left wondering just 'where do we go from here?', sometimes with a sense of frustration.

> "I have tried just about every approach I can think of and still there are so many in the class who I feel are not successfully working out what it is all about. They might try to think about it a bit - I don't know - but they miss the point and I just think some of them are just not up to the stage where they can cope with our ideas... Maybe some of them are simply not trying, it is hard to tell... You find that some of the most enthusiastic, eager and willing types still miss the point."
>
> (Secondary science teacher)

While our procedures for syllabus revision should in theory resolve most of our difficulties with teaching and learning, in practice many difficulties have remained unidentified or unresolved. In 1979 the N.Z. Department of Education provided funds which enabled a group to be established at the University of Waikato with the time and resources to study some of the problem areas in teaching and learning Forms 1-4 Science. A three phase programme of research was adopted.

Exploratory Phase	- 1979 -	to identify key difficulties in the teaching and learning of science at the Form 1-4 level.
In-depth Phase	- 1980 -	to explore in-depth some aspects of these key difficulties.
Action-research Phase	- 1981 -	to find ways to solve some of the identified problems.

This article considers the early work of the project: the Exploratory Phase.

What was actually investigated?

While official syllabus statements could have been taken as defining what Form 1-4 Science is, to have done that would have been to ignore important factors which come into play between this official level and the learner. One of these factors is teachers' lack of familiarity with the official syllabus:

> "To be quite honest with you I haven't had a really good look at the syllabus."
>
> (Secondary teacher)

Another is the attitude of some teachers that decisions about what to teach are someone else's responsibility:

> "A lot of teachers at intermediate school level never see the syllabus. They don't want to see it either. They want to go to their resource person in Science and say 'what do you want me to teach? Give me the stuff and I will teach it'."
>
> (Science teacher with primary and secondary experience)

There is also the strong influence of previous 'successful' teaching experiences,

> "I hatched some chickens in my room a year or two ago... I must do it again, it was incredible... the highlight of the whole year."
>
> (Intermediate teacher)

together with an awareness that for a great many reasons the classroom experience is by no means the same for each pupil:

> "In a large group you have several people working so... you know... and it's a bit of a fight over who does what... I didn't fight... but sometimes you are working with someone and they want to do everything and it's a bit of a hassle and you miss out on something... they do something you don't realise and you miss out on an important step."
>
> (Ex-pupil)

> "A lot of people weren't thinking about it - they just treated science as a bit of a game. Other people just didn't understand some of the terms and things like that..."
>
> (Form 3 pupil)

An awareness of these kinds of factors led us to the view that the emphasis of the project should be on what actually happens in classrooms rather than on the syllabus and resource materials. Thus it was decided to seek out the viewpoints of teachers, pupils, science advisors and others about Form 1-4 Science, to observe what teachers are <u>actually</u> teaching (as distinct from what they think they are teaching) and what children are <u>actually</u> learning (as distinct from what teachers think they are learning).

<u>What methods were used?</u>

Our approach was not the usual survey one, which tends to be based primarily on answers to questionnaires or tests. Rather a range of methods were employed to seek out views and make the observations required.

(a) Unstructured interviews

The project team tape-recorded, transcribed and analysed over 160 interviews with teachers, pupils, ex-pupils, science advisors, administrators, school inspectors, teacher trainers and teacher trainees. Potentially significant comments (such as those quoted in this article) were coded, collated and cross-referenced, enabling possible sources of difficulties to be identified.

(b) Observation

Experienced science teachers working on the project observed a variety of science lessons, under every day conditions. Every effort was made to be unobtrusive and to obtain as complete a record as was possible of both the teacher's and the pupils' involvement in the learning task, their reactions to it, and its immediate effectiveness (see Figure 1).

(c) Structured interviews

A variety of structured interviews were used to find out children's views on aspects of everyday phenomena (see Figure 2), on the nature of science, and to find out their views of their science learning experiences.

What was found out?

The results of the exploratory-phase analyses of observations, and of structured and unstructured interviews, were incorporated in 12 working papers[2] each focussing on an aspect of science teaching and learning which emerged from the data. These papers were circulated, as soon as they were produced, to an audience of teachers, science advisors and others to establish whether they reflected accurately the perceptions of experienced participants in the teaching-learning process.

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2. The titles of these working papers were: Focus on Experiments, Knowledge, Topics, Learner, Teacher, Process Skills, Attitudes, Classrooms, Syllabus, Written Resources and A Visit to a Classroom. Teachers interested in obtaining any one of these papers at cost of reproduction should write to T.O.R. Centre, Hamilton Teachers College, Private Bag, HAMILTON.

The reactions of people to these papers confirmed our opinion that we had indeed identified a number of crucial problems of learning science which deserved further study. These included:

(i) Children do find scientific ideas and theories difficult to understand

Over the past 20 years or so, some rather difficult and somewhat abstract concepts, such as energy conservation, molecules, food chains and so on, have appeared at increasingly earlier years of science teaching programmes, not only in New Zealand but also in other parts of the world.

It appeared to us from our observation that there were considerable difficulties for children attempting to understand certain scientific concepts at an age when they neither have the background knowledge, nor the necessary scientific orientation or 'mental set' to begin to appreciate those ideas and their usefulness. It seemed to us that many children either reject the ideas, distort them to fit in with their own views, or learn them superficially.

(ii) Children have strongly held views about how and why things behave as they do

One of the most difficult considerations which all beginning teachers have to learn is that children think in different ways from adults, and even from each other. Our exploratory-phase investigations of children's concepts showed a remarkable range of concepts of scientific phenomena at all ages. For example, children of various ages were shown a picture of a beach ball rolling down a hill and told that it was gradually getting faster. When asked if there was a force on the beach ball, a 7-year-old said "Yes - gravity", while two 13 year olds thought it might be due to the wind or more probably the slope of the hill. We also found trainee-teachers with naive concepts little different from those of primary school children.

Yet most of the teaching we observed, and textbooks and teaching schemes we read, seemed to be based on the assumption either (a) that children have no concept at all of the phenomenon to be discussed (for example, light); or (b) that they all have the same concept, as the result of having had similar everyday experiences.

Teachers have so little time to really explore children's views, or to build up the learning experiences of the children to take into account their views, or even the views they are likely to hold. What seemed to us necessary here - and what was undertaken in the in-depth phase of the project - was to explore, first, the range of concepts already held by children before teaching begins and, then, to survey the extent to which various concepts were held, from the common to the rare. Armed with this information, we would be better placed, to devise teaching units which built on the range of child-held concepts, rather than the current practice of units which build on how a scientist or curriculum developer logically analyses his own mature concepts. If the learning of scientific concepts was seen by teachers as a process of modifying children's views toward those of the scientists, rather than as a process of teaching new concepts, we believe it would be more successful.

(iii) Science language and everyday language

Another source of conceptual confusion which became strikingly obvious to us through our observations and interviews concerned the use of scientific terms. Many words used in science have both an everyday and a scientific meaning. Usually the meaning of the scientific term is more restricted: for example, work, force, niche, and metal. In some cases, however, the scientific meaning of the word is more extensive than in everyday speech - for example, animal, which for many children refers to mammals, and land mammals at that.

We observed numerous instances in which teachers used a word in the scientific sense and their pupils had interpreted it in the everyday sense. Sometimes a teacher slipped from using the word in one way to using it

in another, almost within a single utterance. It is no wonder, in these circumstances, that pupils acquire some rather peculiar concepts and that teachers of higher classes complain, not without reason, that they have to spend a good deal of their time re-teaching what has supposedly been "taught" before.

This would seem to be a comparatively easy matter to rectify, but to our observation this is not so. It is not easy to recognise whether or not a pupil is using a word in its strictly-scientific context on a particular occasion. It is tiresome for all concerned to have to continually clarify any possible ambiguity but somehow this must be done. It also appears to us that textbooks and teaching materials should be carefully scrutinised for this particular source of learning difficulty, and that teachers should be constantly reminded of it.

(iv) Evidence and experiments

We also observed many problems associated with experimental investigations. For example, often the purpose was vaguely seen by teachers as teaching science concepts and principles, and developing certain skills and scientific habits, as well as providing students with a positive attitude towards science. In attempting all such aims simultaneously there were often serious problems, particularly where priority was given to the teaching of science concepts through what are often called experiments. In this case the label experiment was, as often as not, completely inappropriate for the activity which was taking place. Many pupils seemed to have no clear perception of what they were investigating, nor any understanding of the real purpose of the investigation. The teacher knew in advance what she or he hoped the results would be, and the class knew that the teacher would expect them to get a particular result, even if they did not know what that result was. Our observations, together with the comments of teachers and pupils, showed that all too often "experiments" were not seen by children to require thinking but were simply a game directed towards getting the "right" answer - the teacher's answer. We saw many instances of pupils using subterfuge methods to

get this "right" answer! In other cases, we saw attempts to get pupils to "discover" some information for themselves when in fact the experimental design was such that the desired conclusion could not logically be derived from the observation. Textbooks and teachers resource materials from many countries seemed to us to contain similar confusions. What we were concerned about was the effect of these practices on pupils: the more perceptive children were, the more likely they were to see the unscientific nature of the whole procedure carried out in the name of science.

As we saw it, the problem arose from attempts to make two kinds of statements correspond. Teachers wanted pupils to learn statements ("facts", "explanations") based on theories which have been developed over the centuries by the best scientific brains. They organised an "experiment" to "prove" the statement, based on established theory, but all too frequently what the children observed was slightly different from what was expected, and in any case it was just a single instance from which no principle can be established.

Laboratory demonstrations, individualised "experimental" work and field experiences are undoubtedly very important components in the learning of science, especially when they capture the interest of pupils and at the same time provide enjoyable opportunities for the acquisition of scientific skills. But it seemed to us that in teaching we need to be quite clear about their purpose, whether it be the learning of basic concepts in science, necessary process skills, or the encouragment of scientific habits and attitudes: if pupils sense, as some of the children we talked to did, that so-called experiments do not make sense in terms of the conclusions drawn, they may indeed have learnt the wrong lesson.

(v) Content orientation, process skills and attitudes

The current science syllabuses emphasise the acquisition of process skills, such as hypothesising, systematic observation, objective evalutions of evidence and the like. However, it was our observation that much science teaching was primarily content-oriented. In our view, this was related

partly to traditions in science teaching, to the comparative lack of resource materials, and also to the fact that it is probably easier to organise a content-oriented lesson than to provide practical experience such that each member of the class can develop specific skills. Furthermore, it seemed to us that many teachers were uncertain as to what those skills involve. There should be a vast difference, for example, between looking at an insect moving and observing it movements: if teachers are not clear on the need for system in observing, then their pupils will not be either.

In much curriculum material there seemed to be some confusion between objectives relating to skills and those relating to attitudes. We found it necessary, in our own thinking about these aspects of science teaching, to distinguish between scientific process skills, scientific habits, and attitudes to science. "Skills" were considered to be those thinking processes and actions which are employed in carrying out a particular activity. "Attitudes" were those feelings towards carrying out a particular activity. "Habits" were considered to be associated with carrying out an activity in a particular way. Such habits are partly intellectual and partly attitudinal: it is one thing to know what parallax error is, for example; it is another to have developed the skill to avoid it; but just as important is the habit of mind which incorporates a continuing desire to be as accurate as circumstances require in taking measurements.

It was our opinion from the exploratory phase work, that further analyses were required in this area. For instance, textbooks and teachers often take for granted that children possess the prerequisite knowledge or physical attributes to be able to carry out successfully a particular science activity in the classroom, such as the adjustment of a bunsen burner. Teaching materials are often not sufficiently explicit in their emphasis on the need for specific skills and habits, and on methods of planning for their development. A further problem in this respect is that there are few proven, readily available and familiar procedures for assessing pupils' process skills and habits. Until children's progress can be readily evaluated, teachers have no practicable means of judging the effectiveness of their teaching in this area.

With respect to children's attitudes to science activities, our observations were that most pupils approach their first formal science teaching with high expectations, especially of the chance to do things for themselves in a "real laboratory". By the end of their secondary schooling, however, many of them have been rather disillusioned. There is little doubt that most children are inherently curious and that in science teaching ways have to be found to capitalise fully on this.

What did all these findings lead to?

In the light of the findings of exploratory phase detailed above, and in the light of the responses of teachers and others to questions we posed in the working papers, three areas emerged as the foci for the in-depth phase of the project. These areas were related to one another and had a common theme - that of the learner. They were;

1. Children's science - individual interviews to find out children's views about how and why things behave as they do, and the meaning children have for the words used in science lessons.

2. Children's classroom experiences - observation to find out what learning experiences children have in science classrooms, particularly where they are doing science.

3. Children's outlook on science - individual interviews to find out about children's outlook on science, and what factors influence this outlook.

The work and findings, of the in-depth phase will be explored in a subsequent article.

A class of 13 year olds is instructed to half-fill three test-tubes - one with sugar solution, another with a starch solution and the third with water. To each of these is to be added a few drops of Benedict's solution (blue-green in colour) using an eye-dropper. Finally each solution is to be heated gently and any changes noted. [Benedict's solution reacts with glucose when heated to give an orange-green coloured solution.]

The following conversation comes from a group of boys. The observations [in brackets] are from notes made as they carried out the task.

P1 Did you wash it out?

P2 Yeah, I washed these [test-tubes].

P1 Did you wash the dropper?

P2 Yeah, I will.

P1 Shall I change this [test-tube] because it's got little bits of iodine in it? [P2 had not washed away completely the materials used in the previous task].

P3 It'll be alright.

P2 This is the sugar [adding Benedict's solution to the sugar solution by immersing the eye-dropper in the sugar solution, then squeezing the bulb].

P1 Can I hold it [over the bunsen flame]?

P3 If you turn it on its side it heats up quicker - get the flame like that [tilting the test-tube and lowering it to sit just above the top of the bunsen barrel].

P1 We don't want the glass melting [shifting the test-tube up into the hottest part of the flame]!

P2 Hey it's going - look at the colour.

P1 Yellow.
[P2 adds Benedict's solution to the test-tube containing the starch. He uses the same eye-dropper without rinsing it and the same 'immersion' technique, then holds the test-tube in the bunsen flame.]

P2 It's gone a light green.

P1 A yellow-green colour.
[P2 repeats the procedure in exactly the same way with the water sample.]

P2 What colour? Yellow... It's kind of orange.

P3 They're all the same now.
[At this point the teacher interrupts the class and states that people must be getting their solutions mixed up because groups are getting the wrong results. The pupils are told to repeat the work.]

P3 Why are our tests all wrong? We didn't get ours mixed up.

P2 That's what the teacher said.

P3 I bet you they were right.

P1 I dunno what we did wrong.

Figure 1 Classroom observation of a science lesson Establishing a test for sugar.

Example:

Is there a FORCE on the bike?

No pedalling
No brakes

Slowing down

The following responses illustrate how a non-scientific viewpoint can be retained in spite of 'classroom science'.

"YES... the wheels are still going so that there would be a force from that."

(9 year old in Standard 3)

"It is just putting force on by itself... from the force you gave it before."

(11 year old in Form 1)

"YES... the speed that he has already got up."

(2nd year Teachers College student with S.C. science)

"There is a force because of the bike's own mass... the mass of the bike has come (to) such a speed that it won't just stop straight away... the force is still in there... in the bike... the force was transferred from the person pedalling... and it is now still adherent in the bike... the bike still moves forward."

(2nd year Teachers College student, ex-7th Form physics)

Figure 2 Some typical responses in an interview-about-instances situation. All responses refer to the same non-scientific concept of force.

A REPORT ON THE SECOND PHASE

Roger Osborne, Peter Freyberg,

Ross Tasker and Keith Stead

This is the second of three papers on the Learning in Science Project. The Project was a research investigation funded by the New Zealand Department of Education and based at the University of Waikato. The aim of the Project was to make a study of the teaching and learning of science at the Form 1-4 level, to identify some of the key difficulties in this subject area, and to find ways of overcoming such difficulties.

INTRODUCTION

"You want to know what we do in science? Well you better come up here and sit by me."

(13 year old to a classroom observer)

The first paper in this series discussed the early work of the Learning in Science Project, and outlined the three phase programme of research that was adopted.

The paper also gave details of the exploratory phase of the project. In brief, a large number of structured and unstructured interviews, as well as classroom observations, enabled information to be obtained on many aspects of teaching and learning science at the Form 1-4 level. Working papers produced as the result of this phase enabled findings to be reflected back to teachers and others for comment.

The combined research findings at that point indicated that the in-depth phase of the Project could most profitably focus on the learner and that in particular there were a number of crucial problems in learning science which could be usefully investigated in greater depth. These included:

i) Children make some sort of sense of the world based on their experiences from an early age. However, their views of the world, based on their everyday experiences, together with their understandings of words, based on their common use of language, can be quite different from those commonly accepted by scientists. Children's views are largely unknown but indications are that they have a major influence on children's subsequent learning.

ii) Children's views of the world and meanings for words appear to lead to a mismatch between the ideas and language that children bring into the classroom and those that curriculum developers and teachers expect them to have. This mismatch appears to be causing major problems in the learning of science.

iii) Children bring to science classrooms an outlook on science which does not appear to be fully appreciated, particularly where girls and non-European children are concerned. If science teaching is to positively influence this outlook, this outlook needs to be more clearly understood.

Thus we were led to the need to explore in detail the views of the world children hold, the meanings children have for words used in science, the outlook children have on science, the learning experiences children actually have in classrooms, and how children perceive these learning experiences. Only in this way might we begin to resolve some of the complex issues involved in the teaching and learning of science.

THE IN-DEPTH PHASE

> "You know teachers have got all that knowledge and we are thinking about it differently ... because there are so many ways you can take something in."
>
> (15 year old girl)

Three areas emerged as the foci for the in-depth phase. These areas were related to one another and had a common theme - that of the learner. They were

Children's science - individual interviews were used to explore children's views about how and why things behave as they do, and the meanings children have for the words used in science lessons.

Children's classroom experiences - observations were undertaken of the learning experiences children have in science classrooms, particularly where they are doing science.

Children's outlook on science - Individual interviews were used to explore children's outlook on science, and the factors which contributed to this outlook.

As indicated above, our methods of investigation in the in-depth phase emphasized interview and classroom observation work. In our view, these research methods offered the best chance of illuminating the nature of problems in learning and teaching, and, as well, had the advantage of providing outcomes which were useful to both the project team and to teachers.

CHILDREN'S SCIENCE

> "Spacemen have lead weights in their boots to pull them down ... because there is no gravity on the moon."
>
> (11 year old boy)

With respect to the "Children's Science" aspect of the work of the In-depth Phase, over 500 individual half-hour interviews and at least three man-years of full-time research, investigated children's meanings for the words force, friction, gravity, energy, electric current, particles, living, animal and plant, as well as children's ideas related to weather, light, physical change, and chemical change. Working papers on the results of each of these thirteen investigations have been produced.[2] Some of the results of this work have also been published, or will shortly be published, in science teachers journals.[3] Typically in each study some forty pupils or young people were individually interviewed to obtain the range of views held with respect to a particular word or idea. Line drawings on cards were used to encourage discussion about instances and non-instances of possible concepts associated with the word or idea under discussion. Where appropriate the information from the interviews was subsequently used to devise surveys, which enabled the prevalence of particular viewpoints amongst children to be ascertained.

As an example of such a study we will consider the word 'force'. Using a set of 20 cards, four of which are shown in Figure 1, children's ideas related to the word force were investigated. One significant aspect of the children's views identified by these interviews was that many children considered that force is something <u>in</u> a moving object which keeps it moving. This view, which is relatively compatible with everyday experience and language, is not the accepted scientific view, and such children will have considerable difficulty understanding a variety of other scientific views about motion and the cause of motion. Nevertheless, the above non-scientific view is prevalent and even some pupils who have taken seventh form physics hold it.

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[2] Working Papers No. 14-27, Learning in Science Project, available at cost from T.O.R. Centre, Hamilton Teachers College, Private Bag, Hamilton.

[3] See Appendix.

The three survey questions which were developed to explore the prevalence of this view are given in Figure 2. Response a-a-a represents the correct sequence of responses from a scientific viewpoint while response sequence b-c-a is compatible with the non-scientific idea that the force is contained within a body simply by virtue of its motion and is in the direction of the motion. It is interesting to note in Figure 3 how the prevalence of the response sequence b-c-a actually increases from Form 3 to Form 5. We suspect, that it is not widely appreciated by teachers just how prevalent this non-scientific view actually is, and that pupils often misinterpret what they read and hear so that it continues to support their childhood viewpoint. In the action-research phase of the project this issue is therefore being further investigated.

A second example, also related to the problem of misinterpretation, is found in our investigation of children's meaning of the word animal. In everyday language the term animal is frequently reserved for terrestial four legged creatures. Shop signs say "no animals allowed", we take animals to the vet when they are sick, and we sometimes read in the newspaper statements such as "animals run faster than humans". However from a scientific perspective all living things which are not plants are animals (apart from one or two exceptions, e.g. bacteria, fungi). Nevertheless, in our work,[4] we have found that the everyday viewpoint is commonly maintained by children even in science lessons. A survey of some classes in one group of schools (Figure 4) suggests that children's view of what is an animal varies in an unanticipated way as children move through the primary school. Again we are investigating this problem in the action-research phase of the project.

The central findings from all our work on Children's science was that young children have already acquired meanings for many words used in science lessons, and have relatively clear cut views on how and why things behave as they do. However, unlike the scientific viewpoint which is based on 400, or more, years of intellectual endeavour, children's ideas are more superficially pragmatic and self-evident, being based on, and largely compatible with, everyday experience. More importantly some of these views and meanings appear to be particularly resistant to change, or influenced in unanticipated ways, by science teaching.

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[4] This work was carried out by Beverley Bell (formerly Stead) and reported in her M.Ed. thesis - University of Waikato, 1980.

CHILDREN'S CLASSROOM EXPERIENCES

> "Pupils focus on things that I would never dream of looking at even."
>
> (secondary science teacher)

In our work on children's classroom experiences we attempted to portray the learners' experiences in science classrooms. These portrayals were of two types. Firstly we examined a few lessons in considerable depth using two observers working in the same classroom. This led to a series of working papers which confront the day-to-day realities of teaching and learning science.[5]

In addition to these reports of individual lessons, a much more detailed analysis of some 40 lessons where children were doing science yielded information on reasons why children's ideas are so often not influenced by classroom experiences in the direction intended by teachers and curriculum writers. Basically many problems result from the different perceptions teachers and pupils have of a learning experience. These different perceptions relate to many aspects of a lesson and, whenever they occur, contribute to a situation where the pupils' actual experience is not the teachers' intended experience. A major problem is that the extent of this mismatch is often not perceived by either the teacher or the pupil.[6] Some examples of the types of mismatches that can occur are given in Table I. In our view these problems are neither unique to science nor to primary and secondary schooling nor to New Zealand. However in the light of our research in Children's Science, and our work in children's classroom experiences, we consider that we, as teachers, need to be particularly sensitive to, and explore ways to reduce, the differences in perceptions about the activities pupils are engaged in.

CHILDREN'S OUTLOOK ON SCIENCE

> "One experiment which I can remember quite clearly is wrapping some tin foil around a leaf and putting iodine on it ... that one I found really interesting 'cos I was finding out something for myself you know ... not just for everybody else ... that's the reason why."
>
> (Form 4 girl)

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[5] These papers are known as the "Visit to a classroom" working papers [Working Papers No.13,39,40,41]. They are only freely available because the teachers whose classrooms have been portrayed have been happy that the papers be released for others to read.

[6] Aspects of these ideas are explored further with examples by Ross Tasker in a paper published by the Australian Science Teachers Journal, 1981, 27, 3, 33-37.

Our research on children's outlook on science attempted to confront the real complexity of factors which influence the way children view science and learning-about-science. There are specific influences on children's outlook on science which come from within the classroom - for example children can have difficulty relating what they are doing both to the real world in which they live and the way that they think about that world. The mathematical and analytical thinking required to understand certain aspects of science appears to appeal to only some children. Not all children are enthusiastic about actually carrying out the experimental work themselves.

However, in addition to these classroom influences on children's outlook on science there are a multiplicity of other influences from beyond the classroom. Let us simply indicate some of these issues by including some representative quotations, from our interview studies.

i) Parental Support

"Oh Mum doesn't know anything about science."

(12 year old boy)

"Mum doesn't ask me anything about science whereas she asks me a lot about maths because she knows I'm hopeless at maths. But I have to encourage her to talk to me about science because I like science and I want her to ask me what we did that day in science."

(13 year old girl)

ii) Cultural Background

"The (Samoan) children are used to a learning style which is characteristic of the oral tradition ... where the demonstrators or teachers are always performing and the learners are silent. They watch ... they listen ... there is the use of silent language you know ... gestures, the eyes, the looks, even the expression on the teacher's face can tell a child."

(Samoan adult)

iii) The Image Children have of Science

"(Can you describe what a scientist is like?) He's bald, he's got glasses, and he's wearing a white lab coat and big dark shoes. And he is someone who doesn't listen. He's really involved with science and he doesn't take much notice of the outside world."

(13 year old girl)

In addition, the usefulness of studying science and the status of science compared to other subjects, as perceived by the child, both contribute to children's outlook on science. However, it became increasingly clear to us that these influences can be extremely subtle and frequently act on the learner at the subconscious rather than the conscious level, as well as often acting outside rather than inside the classroom.

REVIEW OF THE IN-DEPTH PHASE

> "A boy is an animal ... we are all animals (why do you say that?) We are all kiwis aren't we?"
>
> (9 year old girl ∿ Std.3, class discussion about animals)

The major result of our work in the In-depth Phase of the project was our increased awareness that some of the central issues and problems in the teaching and learning of science lie embedded in the familiar and the mundane rather than in the exceptional and the dramatic. For example, with respect to children's understandings in science, the problems in learning may well lie not in the long technical words or the complex scientific ideas but in the simple words and simple ideas about how the world behaves. In classrooms, it is teachers' unfounded assumptions with regard to what has become to them, the familiar and the mundane scientific aspects of a lesson that can create unidentified problems for both pupils and teachers. The wider issues of importance in children's outlook on science may be embedded in values and perceptions which seem so self evident to the pupil that they can be overlooked, e.g. a pupil is unaware of the low status he/she places on Science because of the high status implicitly given by the parents to English and Mathematics.

We were also aware that our work raised important questions about what science should be taught, to whom science should be taught, and about the place of technology in the science curriculum. Answers to these questions lie beyond the boundaries of this or any single research Project. However we hope our work will lead to more discussion amongst teachers and curriculum developers about these particular issues.

TOWARD ACTION-RESEARCH

"That's all very interesting but what are you going to do about it?"

(typical teacher comment to reports on the in-depth phase)

With respect to the final action-research phase of the Project, we could not possibly follow up all the problems noted, nor all the content areas considered in the first two phases of the Project. Based on available resources a decision was made to limit action-research to four areas, each area being covered by a group comprised of researchers and practising teachers. The groups were:

(a) a physics group - exploring solutions to issues raised in the working papers Force (No.16), Friction (No.19) and Gravity (No.20);

(b) a biology group - exploring solutions to issues raised in the working papers Living (No.15), Animals (No.22) and Plants (No.24);

(c) a chemistry group - exploring solutions to issues raised in the working papers Particles (No.18), Physical change (No.26) and Chemical change (No.27);

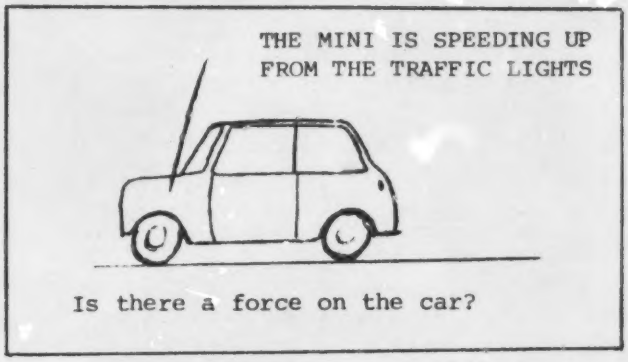
(d) an activities group - exploring solutions to some mismatches isolated in the work on children's classroom experiences (see Table I).

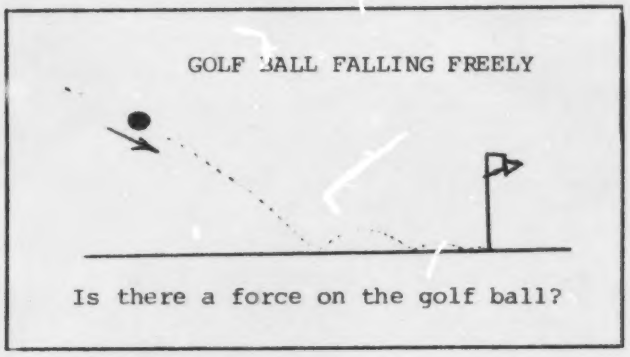
The nature of the outcomes from these groups would depend on the groups themselves. However it was envisaged that practical teacher and pupil guide material of some form would be produced and evaluated in typical classrooms, and, hopefully, be successful enough to be then brought to the attention of a wider audience.

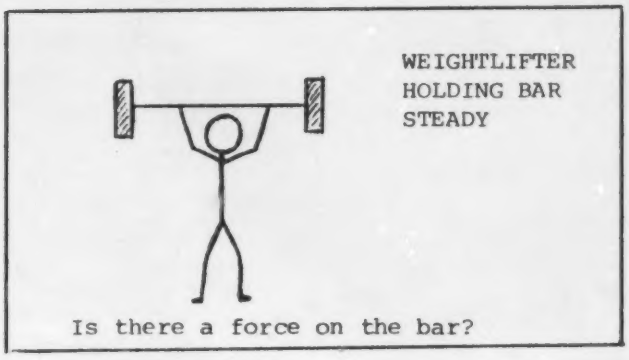
In addition to the outcomes from these groups, there would be a variety of other material which would result from the project . In looking toward editing all this information we were conscious of the necessity of producing material useful to, and useable by, the practicing classroom teacher.

	Some possible mismatches between teacher and pupil perceptions. It would be extremely rare for all these to occur in any one lesson.		Some consequences of the mismatch(if it does occur).
	Teacher's Viewpoint	Pupil's Viewpoint	
Relating to setting the scene of the lesson			
Scientific context of the activity	The activity is seen as part of a related series of experiences.	The activity is seen as an isolated event.	Pupils do not consider the activity against important prior experiences.
Scientific purpose of the activity	The scientific purpose of the activity is specific and obvious.	The purpose of the activity is not obvious.	Pupils invent what seems to them to be a reasonable purpose.
Scientific design of the investigatory activity	The activity has certain critical scientific features which enable particular ideas to be tested.	The critical scientific features of the activity are not appreciated.	Pupils are quite unaware of which aspects of the activity need particular attention and why.
Relating to pupils active involvement			
Doing the activity	The expected pupil actions are obvious and require skills pupils possess.	The actions expected by the teacher are not appreciated and the skills required are not available.	Pupils carry out actions which they consider appropriate, to achieve what they perceive to be the purpose.
Extracting findings	Pupils appreciate the nature of the expected finding, and will extract the appropriate findings when they become available.	The nature of the expected finding is not appreciated and the relative importance of any finding is not clear.	Pupils focus on, and observe, inappropriate aspects of the experimental situation.
Requirement to think	Pupils will consider critically their actions and findings.	There is no awareness that actions and findings should be critically examined.	Pupils perform actions, and accept findings,on face value rather than relating them to the scientific purpose of the activity.
Relating to outcomes achieved			
Evaluation of the experience	The experience will be considered by pupils against ideas and perceptions based on scientists' science.	The experience is considered against ideas and perceptions based on childrens' science.	Pupils have difficulty relating the experience to their view of the world.
Significance of the experience	There are pre-determined significant outcomes which need to be stated or recorded by pupils.	Personal significant outcomes are not related, or relatable, to the outcomes perceived and/or stated by the teacher.	Pupils develop negative attitudes to school science as being not relevant.

TABLE 1. Examples of the types of mismatches that can occur in science lessons.







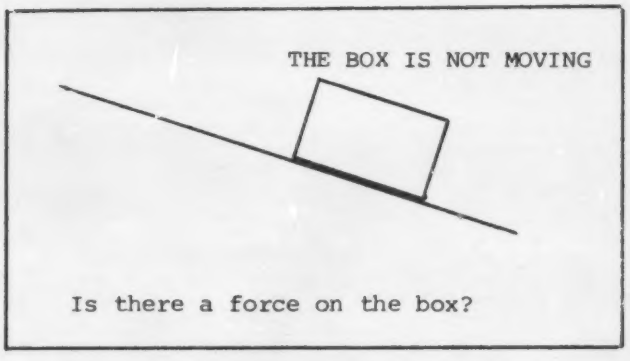
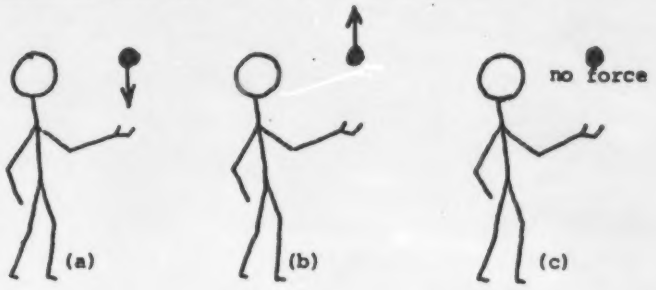


Figure 1: Examples of the interview-about-instances cards

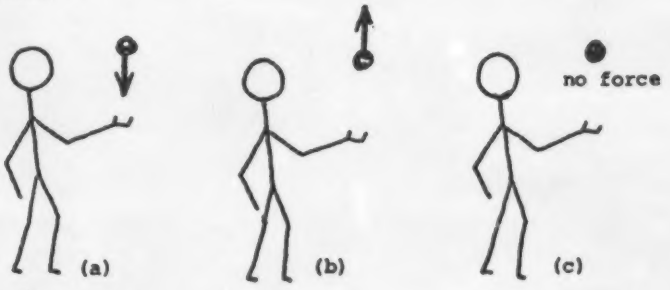
A person throws a tennis ball straight up into the air just a small way.

The questions are about the total force on the ball.

If the ball is on the way up, then the force on the ball is shown by which arrow?



If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?



If the ball is on the way down, then the force on the ball is shown by which arrow?

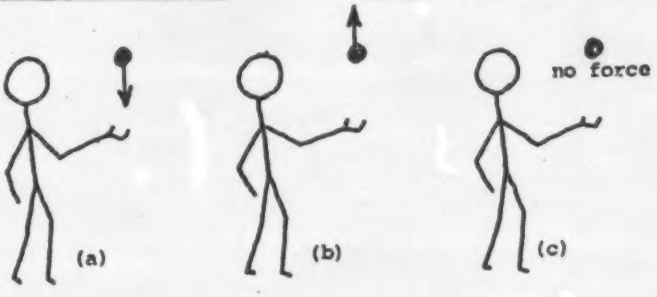


FIGURE 2: Questions used in a survey designed to check the prevalence of a particular view.

PERCENTAGE RESPONSES

	SCIENCE			PHYSICS	
	13 yrs (N = 254)	14 yrs (N = 195)	15 yrs (N = 174)	16 yrs (N = 147)	17 yrs (N = 75)
bca	46	53	66	53	52
aaa	5	11	6	22	19
bba	4	1	1	-	-
baa	14	11	9	4	1
aca	9	5	5	14	21
acb	11	10	10	7	7
(other)	11	9	3	-	-

FIGURE 3: The response pattern to the questions given in Figure 2.

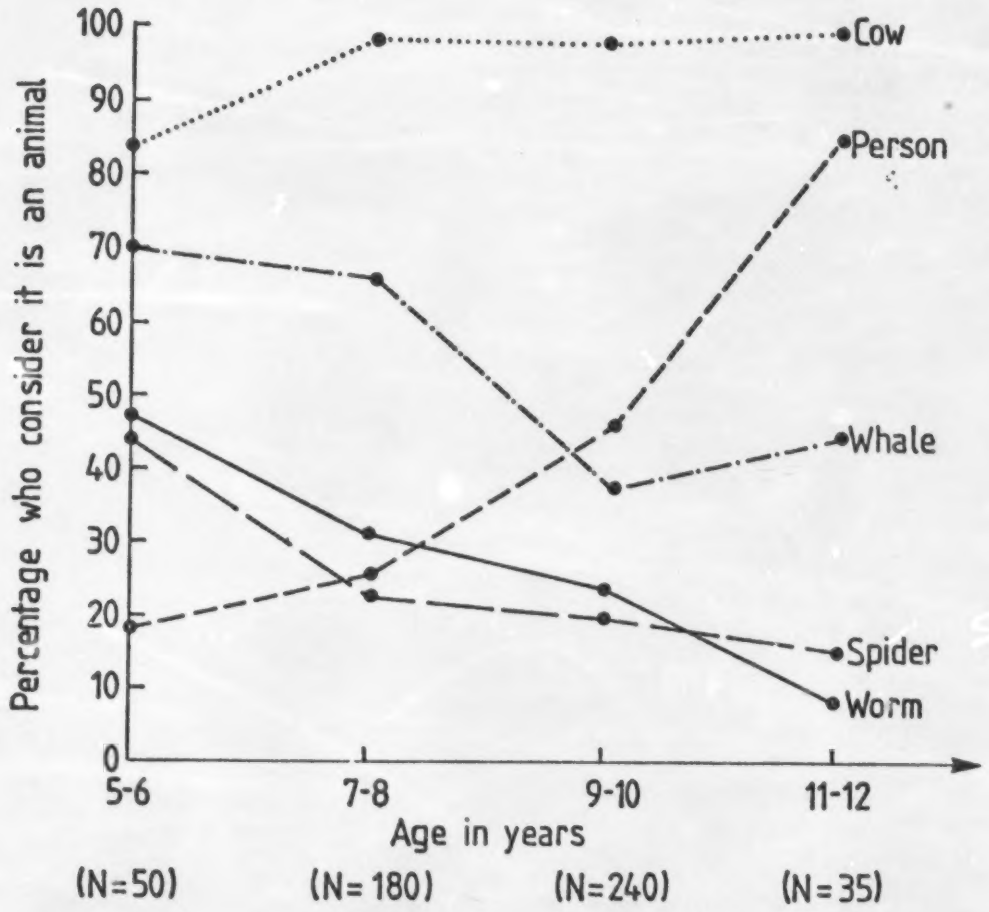


FIGURE 4: Local survey to ascertain the prevalence of particular views prior to an in-service course.

APPENDIX: SOME PAPERS ON ASPECTS OF THE IN-DEPTH PHASE OF THE LEARNING IN SCIENCE PROJECT

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Bell, B.F. An animal is something you take to the vet. Education, (in press).

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Freyberg, P. Conceptual learning and the curriculum. Education, (in press).

Freyberg, P.S. and Osborne, R.J. Who structures the curriculum: teacher or learner? 1981, Set 2, Item 6, Wellington; N.Z.C.E.R.

Gilbert, J.K.; Osborne, R.J. and Fensham, P.J. Children's science and its consequences for teaching. Science Education, (in press).

Gilbert, J.K.; Watts, D.M. and Osborne, R.J. Students' conceptions of ideas in mechanics. Physics Education, 1982, 17, 62-66

Osborne, R.J. Some aspects of the students' view of the world. Research in Science Education, 1980, 10, 11-18.

Osborne, R.J. Children's views on electric current. N.Z. Science Teacher, 1981, 29, 12-19.

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Osborne, R.J.; Bell, B.F. and Gilbert, J.K. Science teaching and children's views of the world. Hamilton, S.E.R.U., University of Waikato, 1981.

Osborne, R.J. and Cosgrove, M.M. Water, ice and steam: some children's ideas. Hamilton, S.E.R.U., University of Waikato, 1981.

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Osborne, R.J. and Gilbert, J.K. A technique for exploring students' views of the world. Physics Education, 1980, 15, 376-379.

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Schollum, B. Gravity - the cost saver. Education, (in press).

Stead, B.F. and Osborne, R.J. Exploring students' concepts of light. Australian Science Teachers Journal, 1980, 15, 376-379.

Stead, B.F. Ecology, Energy and the Forms 1-4 Science Syllabus. N.Z. Science Teacher, 1981, 28, 17-20.

Stead, K.E. What influences a children's outlook on a subject: the case of science. Education, (in press).

Stead, K.E. and Osborne, R.J. What is gravity: some children's ideas. N.Z. Science Teacher, 1981, 30, 5-12.

Stead, K.E. and Osborne, R.J. What is friction: some children's ideas. Australian Science Teachers Journal, 1981, 27, 3, 51-57.

Tasker, C.R. Some aspects of the students' view of doing science. Research in Science Education, 1980, 10, 19-22.

Tasker, C.R. Children's views and classroom experiences. Australian Science Teachers Journal, 1981, 27. 3, 33-37.

Tasker, R. Classroom Activities and their impact on children's views. Education, (in press).

Tasker, C.R. Two lessons in one, 1982, Set No. 1, Item 8, Wellington, N.Z.C.E.R.

Tasker, C.R.; Osborne, R.J. and Freyberg, P.S. Learning in Science Project: considerations relating to approach and methods. Australian Science Teachers Journal, 1980, 26, 3, 79-84.

A REPORT ON THE THIRD PHASE

Roger Osborne, Peter Freyberg and Ross Tasker

This is the third of three papers on the Learning in Science Project (Form 1-4). The Project was a research investigation funded by the New Zealand Department of Education and based at the University of Waikato from February 1979 to January 1982. The aim of the Project was to make a study of the teaching and learning of Science at the Form 1-4 level, to identify some of the key difficulties in this subject area, and to find ways to overcome such difficulties.

INTRODUCTION

In the second phase of the Learning in Science Project children's ideas as they relate to science were investigated. Some typical findings were that

A majority of third formers interviewed thought that;

- a spider is not an animal
- light from a light bulb travels further at night than during the day
- friction only occurs between surfaces in relative motion
- electric current is used up in a light bulb

A substantial proportion of fifth form science students interviewed thought that;

- there is a force in a moving object by virtue of its motion
- electric current is used up in a light bulb
- the bubbles in boiling water consist of oxygen or hydrogen gas
- friction only occurs between surfaces in relative motion.

These and many similar findings led to the view that there are problems in the teaching and learning of science on a scale not previously appreciated. Further investigations involving a wide age range of pupils led us to the following conclusions;

(a) children have strongly held views about a variety of topics in science from a young age and prior to formal learning of science,

(b) children's views are often different to scientists' views, are frequently not identified, but are logical and coherent in terms of the children's experiences and use of language,

(c) children's views often remain uninfluenced, or are influenced in unanticipated ways, by science teaching.

An increasing number of overseas researchers are reporting similar findings.

Some non-scientific ideas (for example, a fire is a living thing) actually become increasingly popular as children move upward through the school system! There are a number of possible reasons for this. For example, one plausible explanation as to why many pupils consider the bubbles in boiling water to be bubbles of oxygen or hydrogen rests with many younger children's belief that the bubbles are made of air. If these pupils then learn that water is made of oxygen and hydrogen, and air consists of oxygen and other gases, it is a small leap to assume that hot water dissociates into oxygen and hydrogen to form the bubbles. Such views can be retained despite considerable teaching - some 40% of Form 7 chemistry students we interviewed held this view.

As a second example of how some non-scientific ideas become increasingly popular, consider a child who believes a spider is an animal. Assume the pupil is then taught, or learns, that a spider is a member of the arachnid family. Reinforced by shop signs that say "no animals allowed", and other similar non-scientific uses of the word, it is not surprising that the child narrows his or her concept of animal to include furry four legged mammals. Is this of any consequence? Unfortunately there is some evidence to show that if teacher and pupil are unaware that they do not share the same meaning for the word animal, teaching about terms like "consumer" and "producer" can simply lead to confusion. (see Bell and Barker, 1981)

These findings suggest that if we, as teachers, are unaware of children's views, differences between teacher intent for pupil learning and actual learning can be quite disparate. Close observations of what goes on during teaching has demonstrated other reasons why it may not always be as effective as we would like. These include:

(a) Pupils consider each lesson as an isolated event while we as teachers assume that they appreciate the connecting links between the lesson and previous learning experiences.

(b) Pupils may invent a purpose for a lesson which is subtly but significantly different to that of the teacher.

(c) Pupils are often unaware or unconcerned about particular design features of an experiment which we as teachers or curriculum writers consider are critical if the pupils are to understand it.

(d) Pupils' background ideas and meanings for words are such that they bring to the learning experience conceptions which influence learning in strange and unexpected ways which we do not always fully appreciate.

Such findings, also, support our contention that we have frequently not taken children's ideas fully into account. Furthermore while children can jump many of the standard intellectual hurdles we place in their path to check on their progress, some do this without real understanding - much of our teaching has been less effective than we might have hoped in changing children's early ideas and basic perceptions.

The work of the action-research phase was oriented to exploring ways to solve these problems.

TOWARDS SOLUTIONS

The nature of the problems just discussed made it an impossible task for the action-research teams to solve them all. We concentrated on looking for some possible solutions to a few specific teaching/learning problems. We considered that the best help we could give teachers would be to devise material which would enable them to become;

i) aware, and even familiar, with the problems related to at least one specific topic,

ii) involved in using teaching material specifically designed to overcome those problems, and

iii) encouraged to seek ways of building on and modifying children's ideas, rather than assuming those ideas to be inconsequential.

Action research was limited to four areas, each area being covered by a group comprised of Project team members and practising teachers. The groups were;

(a) a Physics group - to study problems associated with children's ideas about force, friction and gravity.

(b) a Biology group - to study problems associated with children's ideas about animals, plants and living.

(c) a Chemistry group - to study problems associated with children's ideas about mixing, heating and burning.

(d) an Activities group - to study problems associated with children's ideas about the purpose and intent of laboratory activities.

The common aim of all groups was to produce material useful and useable by teachers, but each group soon came to realise that this would happen only if teachers accepted the proposition that the problems we had identified were applicable to their own classes. The first step, then, was to devise survey materials which would enable teachers to determine for themselves the views held by their own pupils.

For the physics, chemistry and biology groups, it also became clear that if teachers were to modify children's ideas toward the scientists' view, background notes had to be provided not only to explain the views children hold with respect to a particular topic, but also to clarify the contrasting views held by scientists.

Each group aimed to develop a set of classroom activities which attempted to build on, rather than ignore, children's views and to modify children's views toward the scientists' viewpoint.

THE OUTCOMES

The Physics group: The work of the Physics group led to two papers for teachers. The first of these papers (No.33 - see Appendix A) provides background information on children's and scientists' ideas about force, friction and gravity. It includes a survey so that teachers are able to clarify where their own views are with respect to both the children's and scientists' ideas! The second paper (No.34 - see Appendix A) provides a set of teaching activities suitable for the Form 1-4 level. The activities are designed to modify children's views about force toward the scientific

view by taking into account the finding of the in-depth phase that many children have an intuitive idea of momentum. Pre-tests and post-tests are provided so that teachers can evaluate the success of their teaching approach.

The Biology group: While the Physics group concentrated effort on teaching at the Form 1 to 4 level in particular, the Biology group considered how ideas about animal, plant and living could be taught at all levels of primary and secondary schooling. The first of these two papers produced for teachers (No.30 - see Appendix A) enables teachers to appreciate their own meanings for the words animal, plant and living; the meanings that children have for these words; and the meanings that scientists have for these words.

The second paper, (No.31 - see Appendix A) provides a wide variety of teaching activities designed to help children develop a scientific meaning for the three words. For each word the material is designed to force the pupil to challenge his/her own concept, and eventually, finding it to be inadequate, to seek to modify it. The suggested activities allow children to explore instances and non-instances of their own concept and the scientists' concept. Only at the older age levels, scientific reasons why particular objects are categorized as belonging or not belonging to the concept class are emphasized.

The Chemistry group: The chemistry group attempted to develop in children an understanding of some basic ideas which underpin learning in chemistry. In particular they attempted to develop a sound appreciation of what happens when some familiar things are mixed or heated, e.g. water boiling, a candle burning. Where appropriate they introduced into the suggested teaching activities a particle model which could help children explain what they observed. Three papers were produced. In the first paper (No.38 - see Appendix A) children's and scientists' views about the changing of water into ice and steam, is considered. This paper also suggests activities designed to help children gain some understanding of a variety of situations where heating and cooling results in a change of form as well as expansion and contraction. In the second paper (No.36 - see Appendix A) children's ideas of familiar events involving burning, for example a candle burning, are explored and contrasted with the views of scientists. The teaching activities enable children to really appreciate what might be happening when a candle burns. In this way children learn about the chemical reaction involved in a very familiar event. In the third paper (No.37 - see Appendix A) children's ideas about changes that occur when things are mixed

or immersed in other things are considered. Again children's ideas about familiar things are explored, for example sugar dissolving in water, a nail rusting in water. Activities are once again suggested to help children modify their views about these changes toward the views of scientists.

The Activities group: The activities group were centrally concerned with finding ways to reduce some of the teacher intent - pupil learning mismatches discussed on p.2-3, particularly when these occurred in activity based science lessons. The group produced three papers. By using the first paper (No.47 - see Appendix A) teachers can make themselves aware, through first hand experience, of some potential problems in their own classrooms. The remainder of the paper explores, with specific examples, various aspects of the problem area . The second paper (No.48 - see Appendix A) consists of a series of reports from teachers on ideas which they have developed, or used, to overcome some of the problems. The final paper (No.49 - see Appendix A) explores the question of what method or style of instruction is most effective in challenging and modifying children's ideas in science. Arguements are put forward for diverse teaching approaches and for experimentation in teaching. The experiences gained in observing many science lessons led those involved in the Project to the view that successful learning rarely occurs without the active personal involvement of the teacher in guiding the learning.

OTHER OUTCOMES

In addition to the work of the action-research groups, further work has been attempted leading to other outcomes:

i) A small group within the Project has explored issues relating to the teaching of "electric current". This has led to a number of papers on this topic, and the production of a videotape Electric Current. In the videotape, children's ideas about electric current in a simple circuit are explored and a possible way of modifying children's non-scientific ideas is demonstrated. A transcript of the video, VIDEO: Electric Current has been produced as a support paper to be used in conjunction with the tape. (No.51 - see Appendix A)

ii) Other in-service and pre-service course material, including three other video tapes and associated transcripts, have been produced. One of the tapes, Animal, is already available and, with the associated transcript VIDEO: Animals, explores aspects of the work of the Biology Action-Research group. The other two videotapes support the outcomes of the Physics and Activities groups. (No. 51, 52 & 53 - see Appendix A)

iii) A variety of other research projects has developed from the initial project. Many of these are informal studies being undertaken by practising classroom teachers. Other projects are more major and formal and include, (a) extension of the Learning in Science Project (1982-1984) to investigate the teaching and learning of science at the Std.2-4 level, (b) an investigation of children's ideas related to the earth sciences and how these ideas might be modified. Working papers on children's ideas related to SOILS, MOUNTAINS and GLACIERS have already been produced, (c) an investigation of how children's ideas are influenced by reading science textbooks and the nature of text material which will most effectively modify children's ideas, (d) investigations of children's ideas in other subject areas, notably mathematics and social studies.

Much of this research work is based at the Science Education Research Unit, at the University of Waikato. The Unit provides a resource base for these activities and coordinates the dissemination of LISP material and ideas.

CONCLUSIONS:

What has the Learning in Science Project (Form 1-4) achieved and what answers has it produced? Those of us involved in the Project would like to feel that we tackled real and important problems associated with the learning of science. They are complex problems and hence we have no simple answers. Teaching and learning are difficult and complex endeavours.

Nevertheless, we believe that the Project has isolated a major problem in science teaching and learning - our failure to devise a curriculum for our pupils which takes sufficiently into account their ideas about the world and their meanings for words. The material produced by the action-research groups has shown by example the type of material that can be produced to help teachers recognize the problem and bridge the teaching-learning gap.

Furthermore we know that exposure to the ideas of the Project has already modified the ideas about teaching and learning of teachers, particularly in the Waikato. Many of these teachers have not only changed aspects of their teaching but they are now actively committed to finding new ways to establish

children's ideas and to search for, and share with others, teaching strategies which build on rather than ignore children's ideas. The final success or failure of the Project must be judged on how well the findings of the Project are accepted by teachers and on how many teachers come to share the above commitment.

POSTSCRIPT

In the Project we have deliberately focussed our attention on children. In doing so, our appreciation of the child-mind has been heightened. Young children are already budding scientists - active and interested in the world around them and trying to make sense of it. Our job as teachers is to ensure that they retain that curiosity and also come to appreciate and respect, in so far as they are able, the growing collective wisdom of the sciences. It is no easy task.

> "I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the sea shore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

> "If I have seen a little further it is by standing on the shoulders of Giants."
>
> - Isaac Newton

APPENDIX A:

WORKING PAPERS OF THE LEARNING IN SCIENCE PROJECT†

(1979 - 1982)

1. An initial framework
2. Focus on Experiments
3. Focus on Knowledge
4. Focus on Topics
5. Focus on the Teacher
6. Focus on the Learner
7. Focus of Process Skills
8. Focus on the Syllabus
9. Focus on Attitudes
10. Focus on the Classroom
11. Focus on Written Resources
12. Focus on Equipment
13. Visit to a Classroom
14. Reconsidering the framework
15. Living
16. Force
17. Energy
18. Particles
19. Friction
20. Gravity
21. Weather
22. Animals
23. Light
24. Plants
25. Electric current
26. Physical change
27. Chemical change
28. The framework: Toward Action Research
29. Toward Solutions: The work of the Biology Action-Research Group
30. Animals, Plants and Living: Notes for Teachers
31. Teaching about Animal, Plant and Living, Part I/II (2 papers)
32. Toward Solutions: The Work of the Physics Action-Research Group
33. Force, Friction and Gravity: Notes for Teachers
34. Teaching about Force
35. Towards Solutions: The Work of the Chemistry Action-Research Group
36. Burning
37. Reactions
38. Heating and Cooling
39. Visit to a classroom No.2
40. Visit to a classroom No.3
41. Visit to a classroom No.4
42. Portraying children's classroom experiences
43. Children's views and classroom experiences
44. Working in classrooms
45. Interviewing children
46. Toward solutions: The work of the Activities-Action Research Group
47. Science Activities: the Problem
48. Science Activities: specific problems, some solutions
49. Science Activities: Wider issues, some considerations
50. Outlook on Science
51. Video: Animals
52. Video: Electric current
53. Video: Force
54. Video: Activities

NOTES

(a) Papers of direct relevance to practising teachers, No.31,32,33,34, 36-38,45,47-49.

(b) Paper 30 covers aspects of Papers 15, 22 and 24.

Paper 33 covers aspects of Papers 16, 19 and 20.

Paper 36 covers aspects of Papers 18 and 27.

Paper 38 covers aspects of Paper 26.

†Papers available at cost of production through most Teacher Resource Centres or T.O.R., Hamilton Teachers College, Private, Bag, HAMILTON.

APPENDIX B: SOME PAPERS ON ASPECTS OF THE ACTION-RESEARCH PHASE OF THE LEARNING IN SCIENCE PROJECT

Bell, B.F. and Barker, M. Toward a scientific concept of animal. Hamilton, N.Z., S.E.R.U., University of Waikato, 1981.

Osborne, R.; Freyberg, P.; Tasker, R. and Stead, K. Description, analysis and action: three phases of a research project. Research in Science Education, 1981, 11, 52-58

Osborne, R.J. Conceptual change: pupils and teachers. Paper to the Australian Science Education Research Association Conference, Sydney, May, 1982.

RECOMMENDATIONS OF THE ADVISORY COMMITTEE

The Learning in Science Project did not set out to be evaluative. Rather an attempt was made to identify problems in the teaching and learning of science, to explore some of these problems in depth and to seek solutions. Nevertheless, the Advisory Committee of the Project note that the findings of the Project tend to question the effectiveness of some current content and methods of science teaching. With this in mind the Committee recommends that a wide dissemination of the Project's findings and derived methods of instruction is essential to enable teachers to assess the effectiveness of their own instructional techniques and to guide them in modifying these where necessary. The Committee considers the most effective method of dissemination is by direct experience and hence recommend the following:

1) National and Regional Courses

Recommendation: That there be further provision for national, regional and district courses to disseminate LISP work.

Explanatory Note: Two national courses are already planned for teachers college lecturers, secondary inspectors and secondary teachers (June, 1982) and for primary science advisors (November, 1982). Further provision particularly at the regional and district level is sought.

2) Second Level Disseminators

Recommendation: That second level disseminators of LISP be given every possible support.

Explanatory Note: Through the above courses, particularly the National courses, it is hoped that certain teachers college lecturers, science advisors, and teachers will become disseminators of LISP work. If the ideas from LISP are to be disseminated to a large number of teachers the work of such disseminators will be critical.

3) Packages for Teachers

Recommendation: That LISP based kitsets be made available for teachers of science to orient them to learning approaches which have been developed as part of the Project.

Explanatory Note: The second level disseminators will be provided with material which could be used for in-service and pre-service courses. However the ways in which this material can be reproduced and made available to teachers needs further consideration.

4) Future Curriculum Materials

Recommendation: The LISP findings be incorporated in future materials developed by the Curriculum Division.

Explanatory Note: One important aspect of the LISP findings was the incorrect assumptions made by many teachers about learners. It is important that curriculum materials use the work of LISP and other recent overseas findings to ensure that content and methods do not make false assumptions about children's background knowledge, skills and attitudes.

5) Advanced Studies for Teachers' Paper

Recommendation: That the Advanced Studies for Teachers Unit be requested to offer a paper in science education which draws heavily on the LISP work and similar overseas studies.

Explanatory Note: Science Education Courses have been developed on the Waikato Campus which integrates the LISP work, and similar overseas studies, into a coherent course. It is this type of course which is being recommended. The course would expect to influence the way participants think about science teaching and have impact on their own teaching.

6) District Senior Inspectors Conference

Recommendation: That LISP findings be outlined at one of the Conferences of the District Senior Inspectors in Wellington.

Explanatory Note: The LISP work has implications not only for the teaching and learning of science but also in other subjects. The Committee considers a real appreciation of the LISP work is required at the senior levels of the Department.

7) Teachers' Refresher Course Committee

Recommendation: That the Teachers Refresher Course Committee give science education courses based on the LISP ideas and philosophy high priority in the next few years.

Expanatory Note: Various in-service courses and conferences for science teachers already incorporated LISP talks and workshops. The Committee feels that much more of this work needs to be done.